GEOLOGY AS A PART OF A COLLEGE CURRICULUM.

THE demand for scientific studies as a part of the college curriculum is felt by all those who have to do with the provision of higher instruction for American youth. The reasons for this may be various, but a fundamental reason is found in the tendency among the American people in particular, and in this age in general, toward practicality in all things. Applied to education this practicality asks for a training which shall have a direct bearing upon the business of life to be followed immediately after the training period is ended. It means a differentiation of subjects and specialization in methods to adjust the education to the different functions which the students taking it are preparing for. It calls for a professional education for those who expect to become lawyers, doctors, ministers, or teachers,—a technical education for those who are to engage in the arts of the mechanical or civil engineer, or of the architect. It results not only in the establishment of colleges and universities devoted to this kind of education, but it affects the methods of the high schools and academies, and is felt down to primary schools, and on the other hand the older institutions founded on a different plan are adapted to the popular demand by the addition to the regular studies of "electives," chosen not always for their value or disciplinary studies, but because of the practical applicability of the information to be derived from them, to the business of the student.

Without discussing the relative merits of the two ideas of education, the chief contrast between them may be found in the character of the results sought. The knowledge of things and their uses is of chief importance in the practical education; the knowledge of ideas and skill in their use is the aim of the liberal education. Geology is one of the sciences which most men will at

once classify as among the practical sciences. It deals with matters of practical importance to everybody. Coal, iron, the metals, silver, gold, tin, lead, building stone, sand, clay, petroleum, and natural gas, and all geological products are essential materials of modern civilization, and a knowledge of them and of their modes and places of occurrence is one of the requisites of an education, either from the practical or the liberal point of view. So too the dynamics of atmospheric and hydraulic erosion, the agency of rivers and oceans in destruction, removal and reconstruction of geological formations have their eminently practical bearings upon the various arts of engineering. While the practical value of geology is thus evident and undisputed, it is not on this account that its importance as a part of a college course of education is urged. As a practical study geology becomes the center of a group of studies requiring years for mastery. Chemistry and physics are primarily essential to a full understanding of the most common of geological problems. And to use geological facts and phenomena, an acquaintance with the complex methods of engineering, civil and mechanical, which again call for a thorough mastery of mathematics, is necessary. Mineralogy and petrography, metallurgy and mining engineering have each reached a stage of development entitling them to the rank of separate sciences, but the practical training of the geologist should include them all. When we add the biological sciences connected with historical geology, paleontology, zoölogy and botany, with all the laboratory and field work required for their proper study, we have a group of affiliated branches of learning requiring four or five years of continuous study after the student has learned how to study. It is plain therefore that only a specialist, one who is willing to neglect other studies, or who has previously had a liberal training, can perfect himself on the practical side in the science of geology,

But irrespective of its practical uses, as a means of training and supplementary to the ordinary studies of a college curriculum, geology is one of the most useful of the sciences of obser-

vation. It is in providing that particular training to which President Eliot has recently called attention in the *Forum* (Dec., 1892, Wherein Popular Education Has Failed), that geology can be used to such advantage. Speaking particularly of the lower education, President Eliot says it is "the judgment and reasoning powers" that particularly require attention. Their systematic development is to be attained in the four directions of "observing accurately, recording correctly, comparing, grouping and inferring justly, and expressing cogently the results of these mental operations" (p. 421). The attainment of these ends is one of the purposes of liberal education, whether it be in the primary school or in the university. And geology, or any other science, is of value in a college course in proportion to its fitness for the exercise and development of these functions of the student. Geology may be taught without regard to these ends, and then it is valuable from the practical point of view, but when we examine it in respect of its availability as a disciplinary study we find it offering particular attractions.

Using the distinction between theory and practice, which is as old as Aristotle, geology in its theoretical aspect is more easily comprehended than is the theoretical aspect of most of the modern sciences. This arises first from the fact that the facts and phenomena are of a simple and grand nature, making it possible for the teacher to direct certain attention to the specific facts under consideration. The water of the rivers, the mud by the road side, the rocks and sands on the shore are familiar objects to all, and it is a simple matter to call attention by ordinary language to the specific facts regarding them, which analyzed out, are to form the basis of exact ideas and scientific definition and classification. Geology is the one science among the natural sciences which may begin with the common language of the pupil, and by means of such language alone may build up ideas of precise phenomena in scientific terms. Physiography or physical geography surpasses geology proper in this particular, as the admirable work of Professor Davis is showing, and on this account it is the best introduction to geology. But

the very largeness and indefiniteness of the facts are in the way of the use of physical geography for the exercise of the finer and more exact functions of observation. The disciplinary value of classics and mathematics is to a considerable extent derived from this quality, the precision with which the words or figures kindle like ideas. So long as the object of the training is to teach the knowledge of ideas and how to use them, classics and mathematics are the simplest and purest means of developing a liberal education. The addition of sciences to the college course is not because of the usefulness of the knowledge of things thus to be gained, but because the language of the sciences is essential to call forth the observation and the exercise of the accompanying mental operations.

When it comes to dealing with the ideas associated with particular sense observation, where form or motion can not be expressed in simple mathematical terms, language can not communicate a new idea or kindle it in another mind with precision. It is necessary by some means to recall or to present the object itself to the student. In the teaching of science this point is of great importance, and much of the unsatisfactoriness of science-teaching is doubtless due to failure to note it. No circumlocution of words can arouse in another or communicate to him the idea appropriate to a sensation he has never felt. The blind man whose eyes are opened sees men as trees walking.

In the use of science for elementary training (and the training is elementary until the student is capable of investigating and interpreting the facts and phenomena of a science directly) that science is the better which deals with objects which are simple, common and easily observed. Such is geology in some of its aspects. Everytime the student walks in the country he sees the facts discussed in the text-book or by his teacher; and from attention to those with which he is already familiar he can be readily led to observe and give attention to others and to analyze those already in his mind by properly directed questions.

In the field of geology are found the ready means for the exercise and development of observation and thought. The

learner begins with ideas which every intelligent mind associates with the objects described or named, and by degrees the marks of his knowledge are increased, the relations of things are grasped, and the content of his ideas associated with the language of his science is enlarged. In the process of learning the science he has been building up his stock of knowledge of facts and phenomena, but, of more importance than that, he has learned the method of observing and of scientific thinking. He has had training in the methods of reducing the hard facts of nature to the laws of thought and practice, he has seen the method by which theoretical order is made out of the interminable confusion and complexity of natural things.

Beside this primary reason for the use of geology as a disciplinary science-study, there is a second reason arising from the symbolic nature of a large group of its facts. This aspect of the science is best seen in the historical and stratigraphical parts of geology, in which fossils are the chief data for study. The interpretation of a fossil into a species of organism, having its definite place in the elaborate classification of the zoölogist, or as an indicator of the time and place and mode of formation of the strata in which it is buried, is, to be sure, a most intricate and, at first thought it would seem, an unattractive process. But no more so, I would say, than the interpretation of a series of Greek characters. The interpretation of the Greek reveals to us the richest results of human thought and most perfect laws of human speech, and we find therefore in the analysis required the most perfect discipline of the powers of speech and language. The fossil too holds, ready to be revealed, the story of the history of the world and the laws of the evolution of the organic life of the globe, and records an inexhaustible wealth of information regarding the laws of nature. But as an instrument of intellectual discipline its great merit lies in its symbolic nature. It is this symbolic character of the classical languages and of the mathematics which fits them to be universal means of liberal training. The symbolic nature of the fossil fits it to become the exponent of training in the pure science of nature.

The fossil is a mark which stands for something, and thus, in the nature of things, it asks for interpretation. As a symbol it stimulates minute and accurate observation, and kindles close and exhaustive thought; as a symbol it leaves us the ideas it has engendered after it is lost to memory as an observation. Thus the value of its study does not depend upon the retention in the memory of the facts brought before the mind, but in the training of the mental processes required in its interpretation. The study of this branch of geology exercises and develops all the faculties which are specially exercised in any scientific investigation.

Another aspect in which it is an ideal means for such training comes from the fact that it is equally valuable at every stage of progress of the student. When first examined it means nothing to him. He knows nothing of organism, of strata, of geological time. The fossil gains meaning only as he is able to put meaning into it. The student must ask questions, and as step by step he answers his questions by more minute and wider examination, the fossil holds a fuller interpretation. His studies lead him to investigation of the whole field of nature, the rocks, the formation of deposits, the action of the elements, the conditions of life, the forms of organism, their functions and habits, the laws of growth, their adaptation to environment, the changes of events in time, the efforts of association and struggle for life, the principles of evolution, and development—the migration and origin and extinction of organisms on the globe. Nothing in nature is without interest to him. Further than this the amount of good he gains is not measured by the number of fossils he studies, but by the wideness of his research. A handful of fossils from some one fossiliferous ledge may be the text for a year's study, and the methods acquired in the study may be the nucleus of a life's work. In this department of geology the possibilities for new discoveries, new developments of science are almost endless. As a single author thoroughly read develops a wealth of knowledge of the laws of language and thought, so geology may be

studied by the use of a limited set of its phenomena and become the introduction to the exhaustive study of natural science.

Another advantage attaching to geology as a science-study for the college curriculum, arises from the fact that it may be pursued deeply without the elaborate aid to the senses required in other sciences for making minute record or measurement of facts or phenomena. As in language and mathematics, it is essential to acquire a familiarity with the grammar, the dictionary and the symbols, formulas and rules of their usage before the finer training in the use of thought begins, so the vocabulary and the definitions of a science must be acquired before much use can be made of the higher discipline to be derived from scientific study. In language study this higher training comes from practice in making the minute analysis, in detecting the fine shades of meaning expressed in the literature itself. So it is important in selecting a science to be used as a disciplinary study that the facts and laws of nature with which it is concerned should be capable of clear and precise definition, and, moreover, that it should furnish a field for the study of the minute and intricate relationship existing between the different facts which are to be attained by personal inspection of the objects themselves. In most of the sciences this deeper exercise of scientific thought requires for its successful pursuit artificial aids to the common senses of observation. Chemistry must have its purified acids and reagents, test tubes, and delicate scales for measurement of weight and volume. Mineralogy must have its chemical analyses, or optical measurements so fine that microscopes of highest power are essential tools for the investigation. Physics must have the most delicate measurements of time and space and weight. Botany, for the earlier stages of study, is fully equal to geology in these respects, but its scope is much less general, Zoölogy requires dissections calling for skill in manipulation, and in other respects is ill adapted to general classes. But precision in the intellectual processes of observation and reasoning can be cultivated in the use of geological facts to their highest and widest perfection, with scarcely any

aids to the normal faculties of observation. A couple of hammers, a pocket lens, a chisel and a few pointed steel tools for revealing fossils, a tape line, compass and clinometer are the few equipments that will enable the geologist to carry his investigations to almost any degree of thoroughness.

What has already been said applies to the study of the pure science of geology either in the field or in the laboratory. There is still another use to which this, as other sciences, may be put in disciplining the college student in directions not provided for by literary or mathematical studies,—the study of man as an investigator. In the pursuit of the study of geology, the first instruction must be received in didactic form, but after the text-book and lecture stage is passed, or while it is under way consultation of the literature of the sciences is appropriate. In the use of scientific literature the critical judgment is brought under training, and the varying interpretations of well known phenomena by expert scientists suggest the prominent part which the notions already in the mind play in the interpretation of the external facts observed. The experienced geologist will recall many cases of honest report of impossible facts by men who are unable to distinguish between what they saw and the false interpretations they made of these observations. One man will report that a live toad jumped out of the middle of a solid piece of coal, when it was heated in the stove; another will swear that he saw a fossil shark's tooth taken out of a ledge of Trenton limestone. It is evident that our memory of observation is not the revival of the object producing the sensation, but of the idea we framed of the sensation at the time. The study of original descriptions of objects of nature reveals the fact that the describer uses the ideas he already has in his mind as he does the standard foot-rule in his hand for measuring that which he describes, and it is by the study of scientific literature and the comparison of views of many scientists that this highest discipline of the observational faculties is attained—the power to determine the personal equation of error for the observer, and thus see through his descriptions a truer represen-

tation of the facts than the observer himself saw. Geological literature is admirably adapted for this higher discipline, and in no field of science (I think not in astronomy itself) has wider and more comprehensive thought been applied than in geology. While other branches of science have been developed and become more narrow and special in their treatment of the facts concerned, geology still stands as the most comprehensive of all the sciences of nature.

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YALE COLLEGE, November 30, 1892.